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Declass Review by NIMA/DOD

INTER OFFICE CORRESPONDENCE

SUBJECT: Progress Report of 2:1 Reduction Lens (CIA)

STATINTL To:

From:

cc:

- -

Design Development

Initial design attempts using a Hypar and a Tessar, a Triplet and a Tessar were studied. These attempts were abandoned when it became obvious that they would not operate at speeds of F/2.0, due to internal reflection caused by positioning the stop in front.

The Gray design was next attempted and results looked encouraging

STATINTL from the start. [redacted] worked on this development, obtaining a design that was extremely good. However, it was felt that the glass types employed were difficult and costly to obtain and that fabrication of the system in its present shape would be difficult, particularly with regard to the front component of the system.

Several parallel approaches were attempted, utilizing the Gray lens (in the short conjugate component).

Firstly, it was combined with a relatively simple compact telephoto. This attempt was not successful.

Secondly, a good F/4.5 Tessar design was combined with the Gray system. As above, this resultant system, though more promising than the

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previous attempt, developed too much higher order aberration. A correction of the higher order failed.

It was decided, therefore, to return to the Gray Design. A double scaled version in the long conjugate side and the 16" F/3.0 Gray lens on the rear or short conjugate, nearly meets the required performance specifications, though it would be extremely costly to realise.

A careful analysis was commenced by [redacted] STATINTL aimed at preservation of the state of correction and simultaneously simplifying the design, and substitution of less costly common glasses.

The particularly troublesome areas were (1) the cemented triplet, whose diameter would be too large for an even, homogeneous cement contact over the aperture, and (2) the [redacted] STATINTL rare earth glass types incorperated in the design, which are difficult to obtain.

The cemented triplet was replaced by a typical nested type acromatic doublet, of common glasses. The [redacted] STATINTL type rare earth elements were replaced by LaF2, also a readily available, rare earth glass.

Employing these glass types, the system was redesigned to obtain the same state of correction as [redacted] STATINTL obtained in the original system. This degree of correction was obtained.

An analysis of present redesigned system indicates that this lens is extremely well corrected to about 9/10 full field. At this point, the affects of backward curving tangential field and negative tangential coma break sharply into the picture.

Therefore, the remaining task set before us is to correct this problem. There are indications, however, that this will not be a particularly difficult problem to overcome.

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From the inception of this design to the present, it has become increasingly apparent that the glass elements would be costly because of the diameters required.

All glass are in the neighborhood of the glass line, and represent what is considered the best glass element cost. (Glass costs grow with deviation from the glass line), and represent better quality with re-
STATINTL gard to striae and bubble content.

[redacted] was called in for his opinion on selected glass types from the standpoint of glassmaker's delivery time,
STATINTL and quality we might expect to obtain.

[redacted] is currently processing glass for 600mm f/2.0 Ballistic
STATINTL Camera contract which utilizes a Gray lens similar to our present design.

[redacted] states that it is not possible to melt blanks of the design size and meet military specifications on bubble content, unless the glass is made in platinum crucibles.

The affects of high bubble content will cause light scatter of an amount which would be detrimental to performance. It is felt that grade 3 or possibly 2 will be required. With regard to striae, a grade B or C throughout will be necessary.

The field flatteners, however, will have to be at least astronomical quality due to their position in the field and focal plane. BSC-2 was
STATINTL used for these elements. [redacted] opinion on this glass selection would be BSC-1 because it is easier to produce bubble free blanks. This glass type, therefore, has been inserted and design has continued toward completion.
STATINTL We have also made inquiries to [redacted] by mail regarding their ability to melt LaF2 and BaSF6 in quality desired. Comment should be forthcoming.

The glass blanks required will be sizes sufficiently large enough to

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accommodate the following clear apertures and axial thicknesses:

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TYPE GLASS	ELEMENT #	DIAMETER (inches)	BLANK SIZE (DIAM. X TH. IN INCHES)	THICKNESS (inches)	BLANK WT.	FIN. WT.	QUAL.
511/635	1	21.7	23 X 3.5	1.0	130.3	77.2	ASTRO
614/595	2	22.7	24 X 4.5	4.3	254.5	177.0	B
620/603	3	21.6	23 X 3.5	2.7	174.6	116.5	B
720/293	4	18.6	19.75 X 6.5	5.0	324.4	273.7	B
511/635	5	17.2	18.5 X 2.5	2.2	60.2	39.4	ASTRO
(667/418) BASF-6 OK	6	12.2	13.25 X 1.5	1.0	28.3	20.8	B
(744/449) LAF-2 OK	7	11.1	12.25 X 2.25	1.8	39.3	26.0	B
(744/449) LAF-2 OK	8	11.1	11.25 X 1.25	1.0	18.4	8.7	B
(667/418) BASF-6 OK	9	10.4	11.25 X 1.25	0.6	17	9.0	B
511/635	10	12.8	13.5 X 1.375	1.1	17.6	7.6	ASTRO
720/293	11	13.3	14 X 4	2.6	100.3	75.3	B
620/603	12	14.5	15.75 X 2	1.5	47.3	21.9	B
614/595	13	15.4	16.25 X 2.5	2.2	64.8	29.6	B
511/635	14	11.6	12.25 X 2	.6	21.1	11.8	ASTRO
					1798 lbs	894 lbs	

It should be noted that our queries to the glass makers have been in regard to availability of these common glass in massive size and not, at this time, with regard to price.

Requests issued asking for price & delv-3/23.

RJH:cs

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Note:

Design complete - being evaluated - 3/24

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Final Engineering Report

SUBJECT:

The design development of a prototype 2:1 reduction printer lens having the following specifications: 16" EFL f/2.0 diffraction limited system operating at an object format and an image format of 18 inches X 18 inches and 9 inches X 9 inches, respectively.

ABSTRACT:

In order to obtain the design objectives and the required imagery, a study development period was initiated. The large format sizes together with a relatively long focal length and high relative aperture perforcely indicated that an advance in the state of the art was required.

SUMMARY:

The initial design philosophy adopted consisted of several parallel approaches. Specifically, these endeavors consisted of separate design activities involving plausible lens forms for the front and rear conjugates to be subsequently combined to form the overall 2:1 system. Each lens form so adopted was corrected and combined with particular regard to the lateral aberrations, as illustrated below to obtain the best possible solution consistent with the time requirements.

a. Triplet: Tessar
b. Hypar: Tessar
c. Triplet: Modified Grey Lens
d. Compact Telephoto: Modified Grey Lens

All of the above solutions were afflicted with considerable higher order aberrations. In an attempt to preserve the third order solution and

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simultaneously balance the high order terms in each case, a higher order contribution program for the LGP-30 electronic computer was written. Only limited success was achieved, however, with this valuable tool and it was primarily with regard to the combination of a compact telephoto and the modified Grey lens. However, this particular system displayed considerable sagittal curvature of field and distortion to be considered worthy of continued design effort. Therefore, this particular design activity was suspended in favor of a more virgin approach.

It was considered worthwhile, consequently, to direct our efforts towards hemi symmetrical systems, containing relatively shallow curves. Hemi-symmetry about the stop has distinct advantages in that distortion, coma and lateral color are substancially minimized from the beginning. The shallow curves contribute a minimum of higher order and the designer has considerable freedom to correct the remaining aberrations.

The Grey lens (basically a triplet which has been compounded and split into several elements) became the object of a rigorous design activity. A substancially well corrected system, 16" EFL @f/3.0, was scaled to 32" EFL @ f/6.0, the former and latter combined to achieve the desired design objective of a diffraction limited 16" EFL @ f/2.0. A cursory look at the system indicated the following faults:

a. Several cemented surfaces which could be difficult to cement due to the large area of application.

b. Too many elements to be economically feasible.

c. Several rare earth glasses compounding the high glass cost estimates.

This system was, therefore, reexamined to simplify the design, improve its performance if possible, and reduce its cost since it became increasingly

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apparent that the glass elements would be extremely expensive due to the diameters involved.

Four elements were subsequently removed, all cement contacts broken, and common glass in the neighborhood of the glass line substituted to achieve the lowest possible glass costs.

The design appeared to meet the objectives in all respects, its form and adaptability to manufacture were considered plausible. Consequently, the study program and system synthesis was considered completed.

ANALYSIS:

An analysis of the design commenced with considerable ray tracing of full field in three wavelengths within the optimum spectral range. Spot diagram and radial energy distribution analysis followed. The system analysis indicates that diffraction limited imagery had been achieved based on the geometrical theory. A correlation of spot diagram and the energy distribution within the geometrical "blue circle" strongly indicate that the geometrical image will be small compared to the diffraction pattern.

A. Performance - Furthermore, based on the Rayleigh criteria, which has been demonstrated to be in close accord with the geometry of the airy disc, hence a test for diffraction limited imagry, the following results were obtained:

RAYLEIGH TOLERANCES

Aberration	Allowable Value	Actual Value
Longitudinal Color	± 000378	- 000376
Marginal Spherical	± 001575	+ 001700
Zonal Spherical	± 002200	- 001790
Tangential Coma	± 0001417	- 001643
Sagittal Coma	± 003937	- 003116
Astigmatism	± 000189	-0000008
Airy Disc. Radius		.000056"

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The system is free of astigmatism and distortion, and accordingly, the H' vs Tan U' plots reveal uniform linearity about the principal ray for the tangential and sagittal fans, with exception of the extreme upper and lower rim rays. Since these rays will reduce the image contrast it was decided to vignett these troublesome rays, consequently compromising relative illumination. Table II indicates the relative illumination as a function of image height.

Image Height	Rel.Illum.
Axis	100%
.66 Field	83.1%
Full Field	67.3%

Table II

B. Wavelength - A plot of the longitudinal color as a function of wavelength indicates that the system is corrected toward the blue. The mean wavelength is in the neighborhood of F (486.1 mu) and is recommended as the monochromatic source to be utilized. The spectral range of correction is the interval h to C (404.7 mu to 656.3 mu).

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C. Resolving Power

Since the net resolution obtainable with this system is a function of lens and film emulsion predictable by the formula by Katz

$$\frac{1}{R_L} + \frac{1}{R_F} = \frac{1}{R_T}$$

Where

R_L = lens resolution
R_F = film
R_T = total resolution

The following study is set forth with regard to the relative aperture

Speed	Emulsion	Resolution
f/4.0 @2:1	Aerial	232 l/m
	Panotomic X	91.1
	Microfile	101.4
	High Resolution	188.3
f/3.0 @2:1	Aerial	309 l/m
	Panotomic X	101
	Micro File	113.8
	High Resolution	236.1
f/2.8 @2:1	Aerial	328 l/m
	Panotomic X	102.9
	Micro File	116.2
	High Resolution	247.0
f/2.0 @2:1	Aerial	464 l/m
	Panotomic X	113.4
	Micro File	129.7
	High Resolution	316.9

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D. Glass Size

Glass blanks of the size prescribed for this application are of the following size:

ELEMENT #	DIAMETER (inches)	THICKNESS (inches)
1	21.7	1.0
2	22.7	4.3
3	21.6	2.7
4	18.6	5.0
5	17.2	2.2
6	12.2	1.0
7	11.1	1.8
8	11.1	1.0
9	10.4	0.6
10	12.8	1.1
11	13.3	2.6
12	14.5	1.5
13	15.4	2.2
14	11.6	.6

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E. Glass Quality

It should be pointed out that glass blanks of a sufficient size to accommodate the large free apertures will have to be melted in platinum crucibles to meet military specifications on bubble content.

Since the glass quality is of major essence in the attainment of a diffraction limited system, it is considered necessary to supply the following specification to glass quality

a. Field flattener lens to be astronomical quality

b. All other elements

Grade B or C with regard to straie

Grade 3 or 2 with regard to bubble content

F. Glass Costs

Based on the determined glass quality, four glass manufacturers were invited to submit quotations.

A tabulation follows summerizing these cost quotations.

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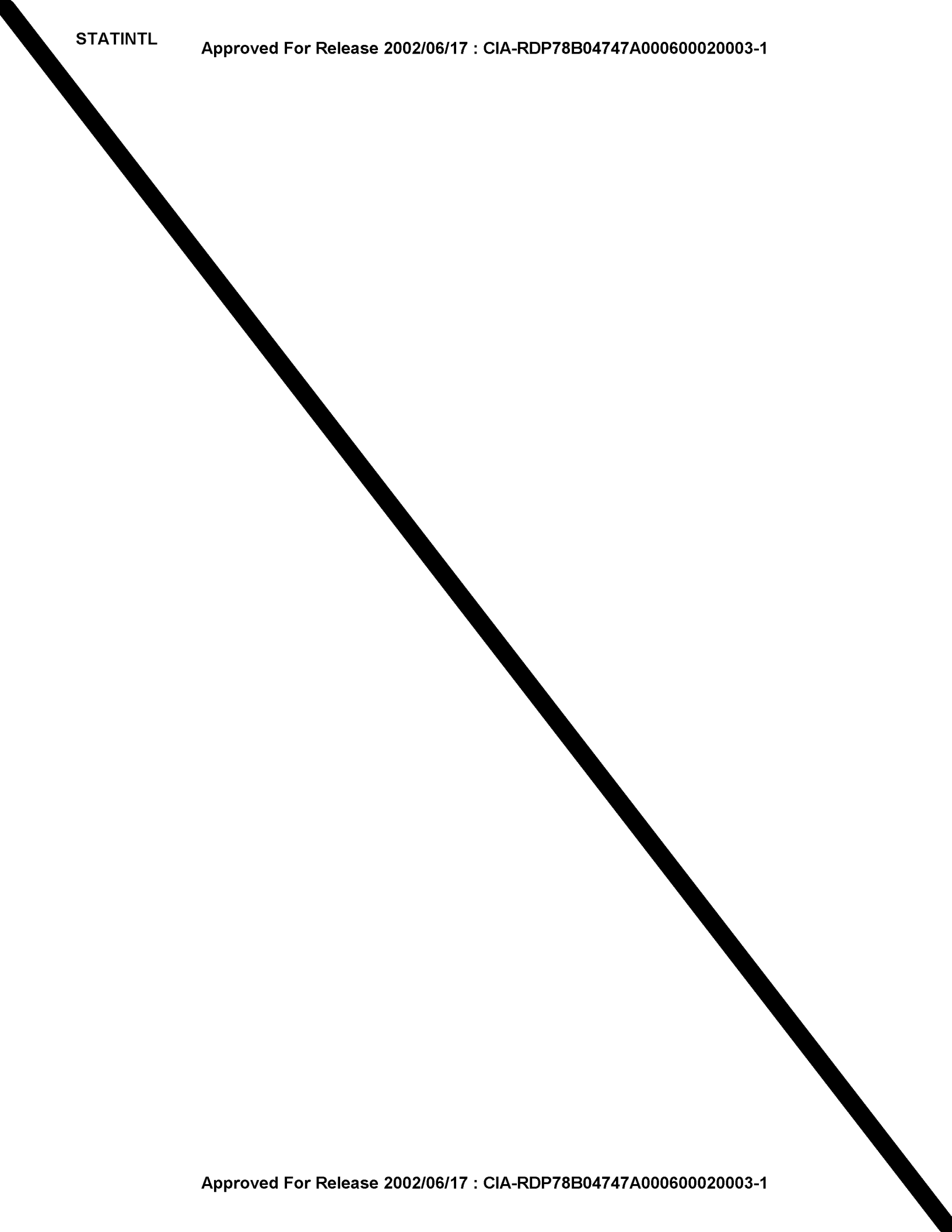

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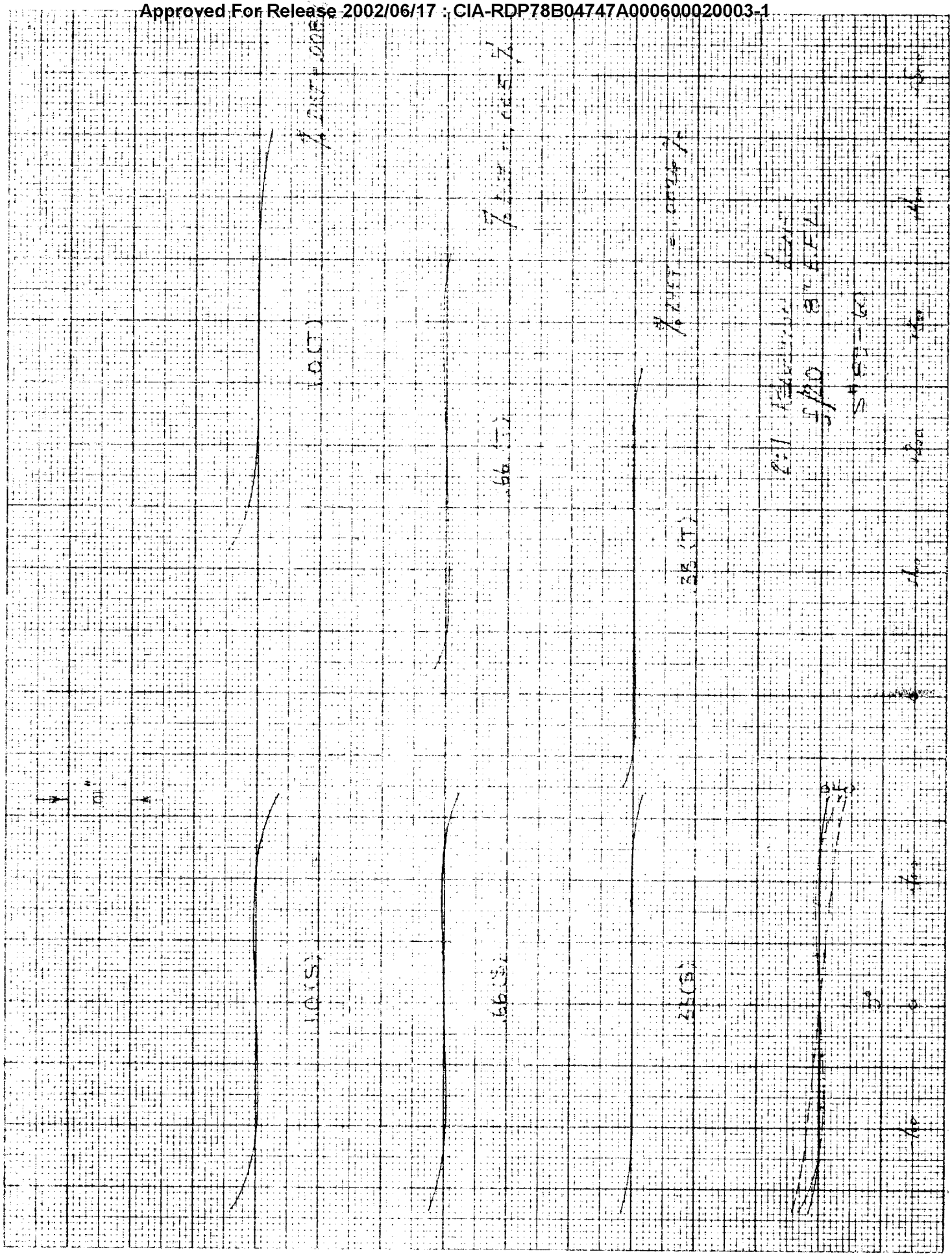

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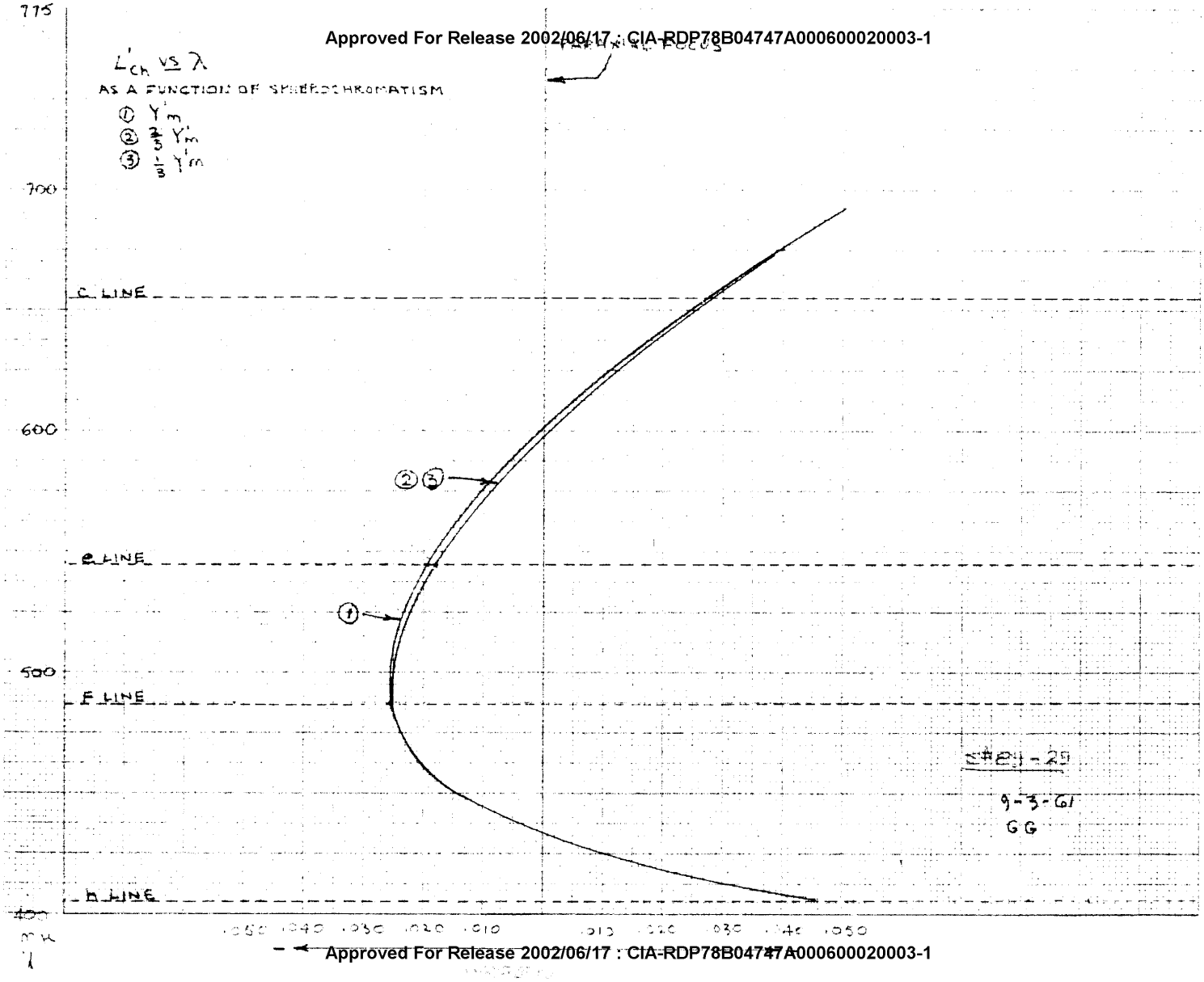

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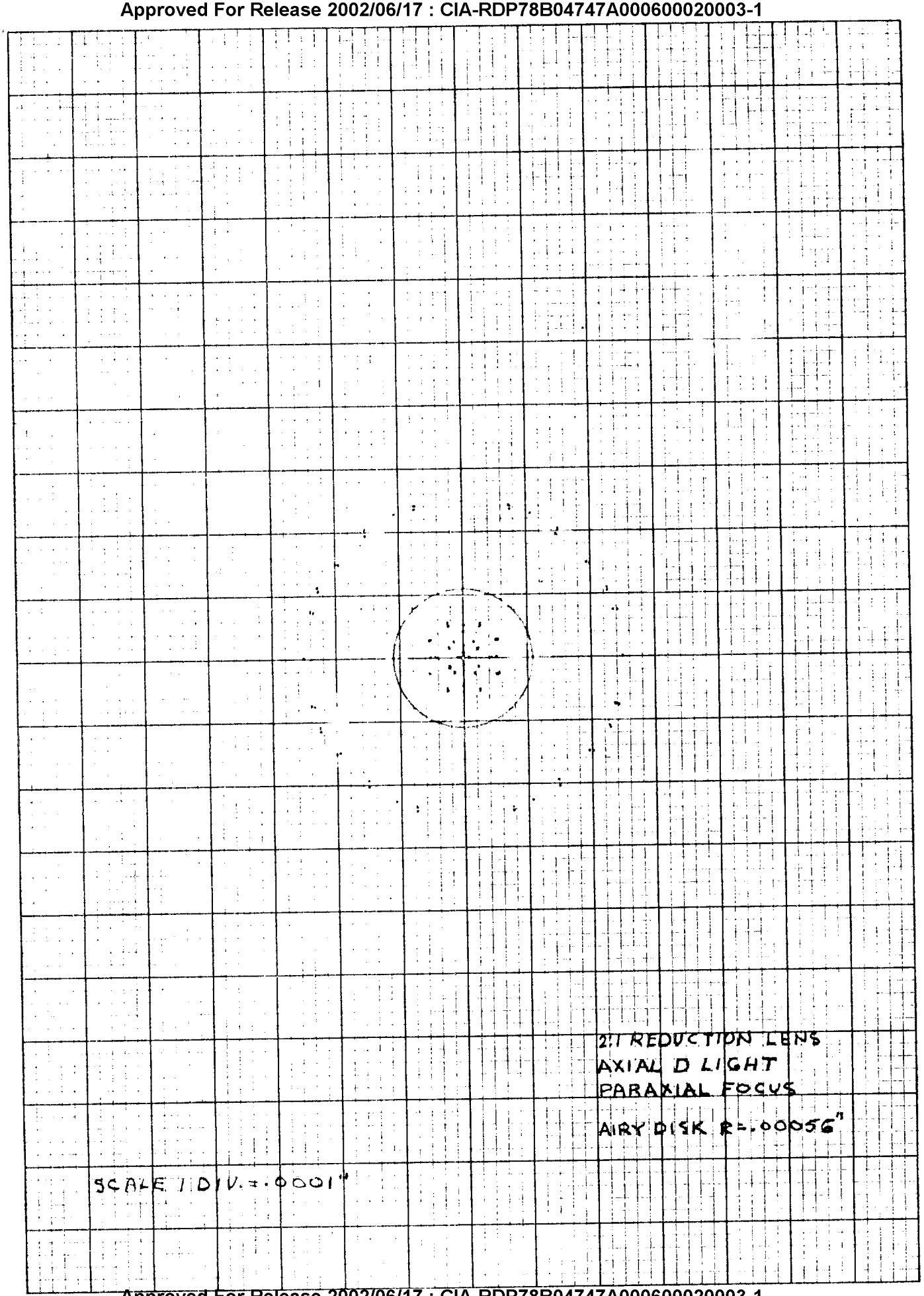

5 X 5 TO THE ½ INCH 359-6
KEUFFEL & ESSER CO.

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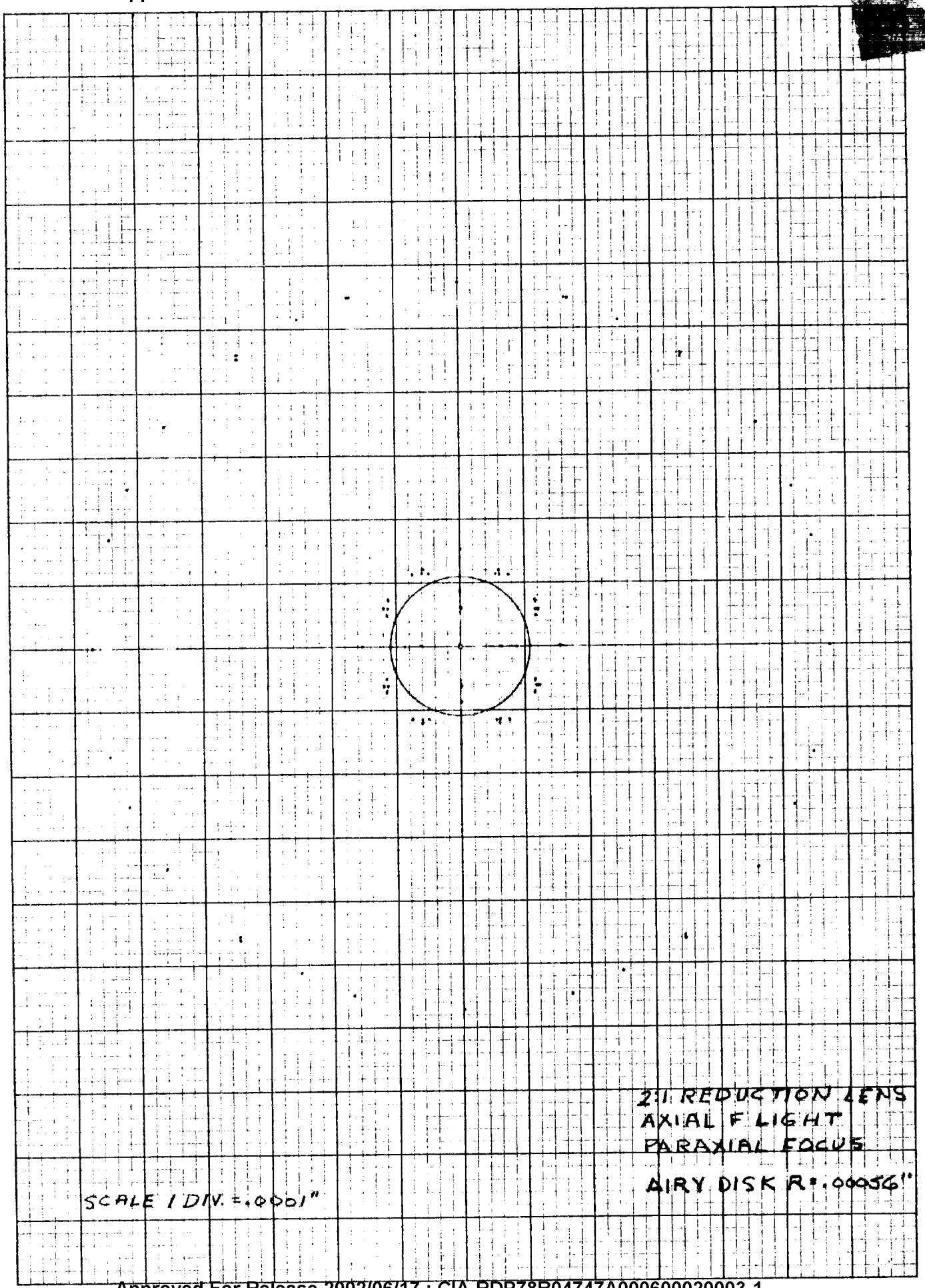

359-6
5 X 5 TO THE ½ INCH
KEUFFEL & ESSER CO.
MADE IN U.S.A.
K&E

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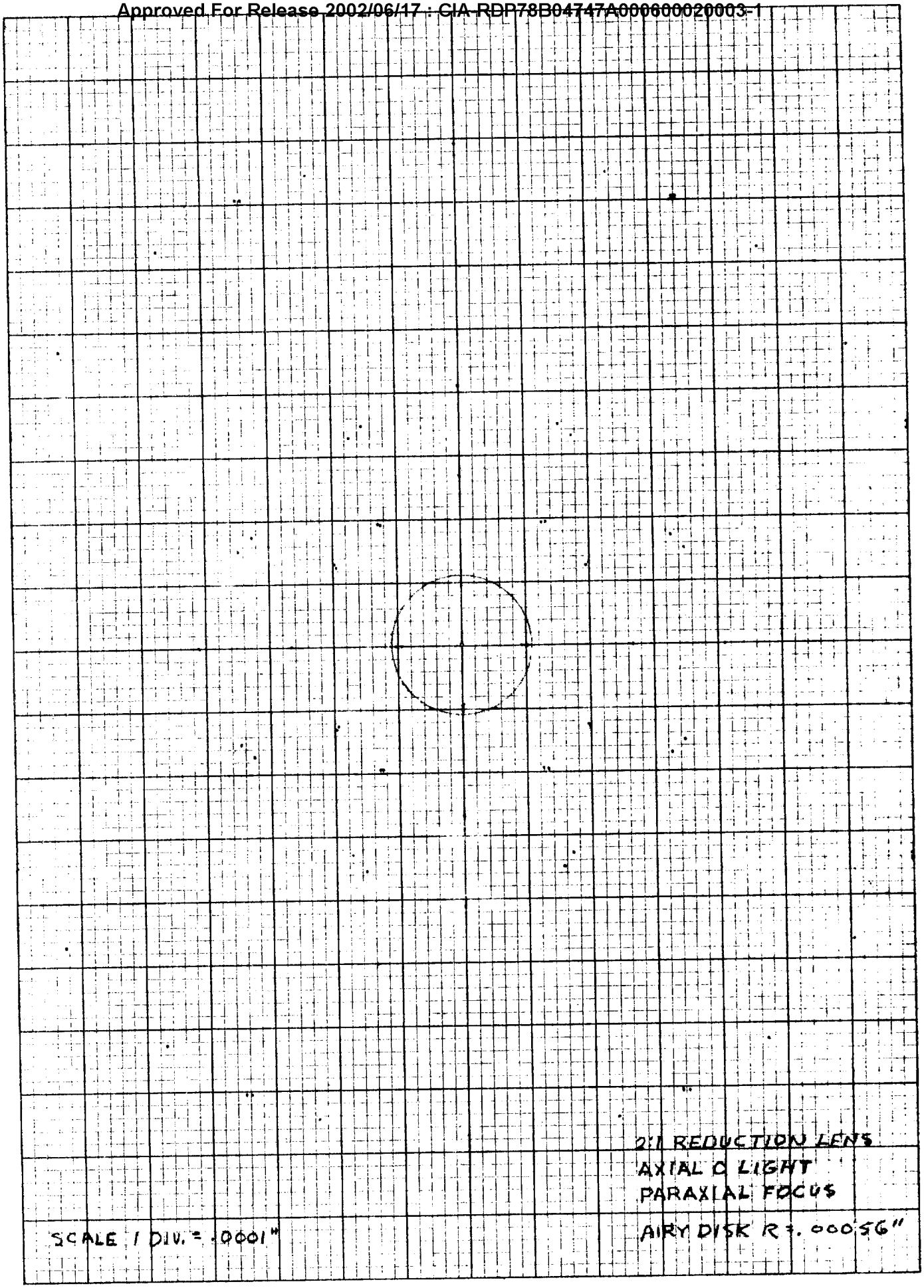

359-6
5 X 5 TO THE ½ INCH
KEUFFEL & ESSER CO.
MADE IN U.S.A.
K&E

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